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LEARNING

Fostering students' epistemic agency through the co-configuration of moth research

David Stroupe | Marcos D. Caballero | Peter White

Michigan State University, East Lansing, Michigan

Correspondence
David Stroupe, College of Education, Michigan State University, East Lansing, MI 48824.
Email: dstroupe@msu.edu

Abstract

We argue that students should take on roles as *epistemic agents*—those who shape knowledge production and practices of a community. In this study, the research team—a science educator and two scientists—worked with a sixth-grade teacher to provide 90 students with opportunities to take up epistemic agency over a 22-day unit about moth ecology. We used cultural historical activity theory (CHAT) to analyze the co-configuration of activity. During planning, tensions arose among the research team around how and why to position students as epistemic agents, while still attending to meaningful science questions. During instruction, students prompted the constant negotiation of epistemic roles and practices as they acted on shifting agentic participation structures.

KEYWORDS

co-design experiment, cultural historical activity theory (CHAT), epistemic agency

1 | INTRODUCTION

For years, multiple initiatives have directed students to learn science differently than memorizing facts and conducting confirmatory activities, culminating most recently with the Next Generation Science Standards, which propose that students should participate in disciplinary practices (Achieve, 2013). While such efforts are laudable, two complex issues about students' participation in disciplinary practices make such goals difficult to achieve. First, there is little consensus about the epistemic roles students should take on when they engage in disciplinary practices. For example, students could be positioned solely as *technicians*, whose primary task is follow certain practices deemed important by someone with power (Manz, 2015; Russ, 2018). For example, technicians are responsible for manipulating equipment, answering questions asked by an authority figure, and maintaining the order of site of science (Latour, 1987; Shapin, 1989). However, technicians are not permitted to create and shape the epistemic practices of a disciplinary community, such as asking questions, creating and revising explanatory models, and determining criteria for evidence.

We argue that framing students solely as technicians skews their view of their current and future participation in science; students see that they can engage in certain rote aspects of daily science work, but are not permitted to shape knowledge production and practices of a community, which some researchers describe as *epistemic agency* (Damsa, Kirschner, Andriessen, Erkens, & Sins, 2010; Dotson, 2012; Miller, Russ, Stroupe, & Berland, 2018; Stroupe, 2014). When students are framed as technicians, they learn that the teacher is the solitary epistemic authority in the classroom.

The second issue that complicates efforts to support students' participation in disciplinary practices as epistemic agents is that such participation requires the development of a learning community in which teachers and students feel safe to engage in complex epistemic work (Berland et al., 2016). In many classrooms, epistemic boundaries are clear—teachers deliver the "correct" canonical information to students, who subsequently reproduce information and methods privileged by the teacher or other instructional authority, such as a visiting scientist (Cuevas, Lee, Hart, & Deaktor, 2005). The implicit assumption in these classrooms is that the job of teachers or other instructional authorities is to provide students with the proper ways in which to make sense of the world, rather than rely on ideas and experiences that may not align with certain canonical norms, and can subsequently impede learning (see Barton & Tan, 2010). However, students in such classrooms are less likely to engage in disciplinary practices with epistemic agency if they feel that their ideas and experiences are "wrong" and a hindrance to success (Bang, Warren, Rosebery, & Medin, 2012).

These two issues involving shifts in expectations for students' participation in disciplinary practices through epistemic agency, as well as efforts to understand how such shifts are possible, prompted our collaboration and this study. As science educators and scientists, we wanted to provide students with opportunities to participate differently in disciplinary practices by supporting their shifting participation as emerging epistemic agents. Given our foundation and goals, we engaged in a collaboration that was novel for each researcher —we coplanned and cotaught three sixth-grade classes with a teacher (Jake). The focus of our 22-day unit was ecology, and given the expertise of Author 3, White (an entomologist), we planned for students to leverage local moths (order *Lepidoptera*) to learn about ecology while designing and conducting research projects that emerged from their observations and life experiences. Additionally, we hoped that data from students' research projects could contribute to the research conducted in White's laboratory given his role as an ecologist at a large midwestern university. Finally, we wanted to understand our changing roles as researchers as we attempted to provide students with opportunities to take up epistemic agency.

2 | PROBLEM FRAMING

We recognize that partnering classrooms and scientists to help students engage in disciplinary practices is not a new idea; however, we propose that our purposeful attempts to help students learn through shifting epistemic roles differs from many initiatives. For example, the National Center for Science Education offers a program called "Scientist in the Classroom" (https://ncse.com/scientistinclassroom), in which scientists make an initial visit to classrooms to talk with students about their research. Following this visit, the scientist returns to facilitate an activity or lesson with students. In another example, the MIT Edgerton Center offers "academic field trips" in which a teacher works with a scientist to identify a curriculum topic that students will learn (https://edgerton.mit.edu/node/86). On a prescribed day, the teacher and students travel to the scientist's research site. The scientist then provides space for students engage in an activity that highlights the curriculum topic.

While each of these examples offers opportunities for scientists, teachers, and students to interact, we argue that in each experience, scientists appear to be positioned as the sole regulator of knowledge and practices—the solitary epistemic agent. Students remain technicians; they observe someone else's disciplinary practices and participate in work deemed by the scientist as important, but do not have opportunities to shape the knowledge production in classrooms. Therefore, we wanted to create opportunities for students to be positioned with, to perceive they that they can act, and to act with epistemic agency (Miller et al., 2018) to help advance local science research of White.

We began by using cultural historical activity theory (CHAT) to frame this work. CHAT provided the lens of the co-configuration of activity, meaning that participants in an emerging activity system negotiate new forms of work, rules, and solutions to problems, often in real-time (Engeström, 2004; Penuel, Cole, & O'Neill, 2016; Plakitsi, 2013). In this study, co-configuration provides an analytical lens to understand how the different participants—science educators, scientists, a teacher, and sixth-grade students—attempted to negotiate new epistemic roles while designing and conducting Lepidoptera research.

While CHAT is a useful analytical tool, we were careful to avoid an assumption about the actors in activity systems; namely, that every person, by simply existing in a location, is treated on equal epistemic terms as every other person. We argue that CHAT —a theoretical framework often used to analyze interactions between adults—may not explicitly account for inherent power differences between adults and children engaged in co-configuration work. As noted previously, students—children—are often excluded from the same plane of activity as adults with regard to epistemic agency by being positioned as technicians. However, we argue that co-configuration requires that all participants develop epistemic agency—that everyone, to some degree, is allowed to propose and shape the community's knowledge production and practices. Therefore, we wanted to know how we, as researchers, might purposefully help elevate students to the same epistemic plane of activity as adults by providing them with opportunities to be positioned with, to perceive that they could act, and to act with epistemic agency to conduct Lepidoptera research.

Given the multiple conceptual lenses involved in this study, we summarize the two main research questions:

- How did adults in this study plan and enact opportunities for students to be positioned with, to perceive that they could act, and to act with epistemic agency?
- How does students' shifting epistemic agency shape their learning opportunities as the research team and students co-configured Lepidoptera research?

3 | THEORETICAL FRAMING

In this section, we describe CHAT, and explain why we selected the framework for this study. Next, we propose that this study contributes to CHAT-framed research in two ways. First, we propose that a key feature of co-configuration is the capacity for participants to develop epistemic agency. Second, we argue that not every participant in activity systems is permitted to take on similar forms of epistemic agency. Therefore, we use Harding's (2008) notion of "sciences from below" to examine how students, often marginalized epistemic practices, can be elevated to full participation in an activity system.

3.1 | Cultural historical activity theory

CHAT, a theoretical framework used with increasing frequency in education research, expands on activity theory in two ways. First, CHAT researchers try to understand how interactions between participants, system objects, and practice histories generate knowledge and tools within activity systems (Fenwick, 2006; Saka, Southerland, & Brooks, 2009; Schwartz, 2012). Within activity systems, the actions of individuals occur at the nexus of multiple factors: the tools and artifacts available, the rules, and the division of labor working, and the object (the problem or goal; Engeström, 1987; Thorne, 2004; see Figure 1 for an overview from Engeström, 1987). Second, CHAT focuses on networks of interacting activity systems, and how knowledge and activities change when participants navigate contradictions that arise when they attempt to communicate, coordinate, and collaborate practices in response to novel problems (Edwards, 2007). If particiants can successfully create practices and a shared vision to solve emergent problems, the initially disparate activity systems become co-configured (Engeström, 2004).

CHAT has been used broadly in education research to examine complexity of human learning within and across settings from system perspectives. For example, the *Journal of the Learning Sciences* commissioned a special issue to highlight how CHAT may help researchers involved in design-based and longitudinal research (Penuel et al., 2016). While many CHAT studies examine large organizational change, other research utilizes the framework to investigate smaller units of analysis. For example, Sezen-Barrie, Tran, McDonald, and Kelly (2014) used CHAT to examine how preservice teachers made sense of a microteaching experience.

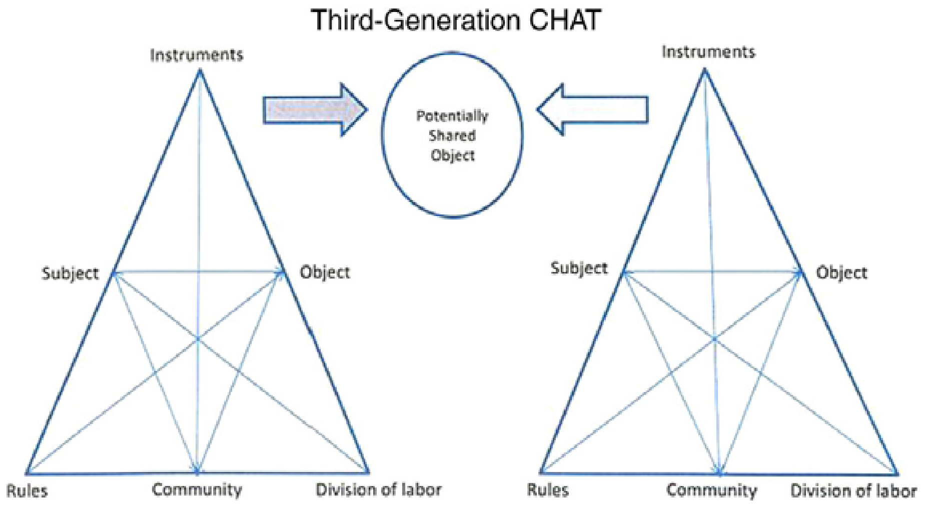

FIGURE 1 Engeström's (1987) diagram for modeling interactions among components of activity systems. A *subject* is an individual or subgroup whose agency is, in the emic sense, the perspective or point of view of the analysis. The *object*, as Engeström describes, is the 'raw material' or 'problem space' at which the activity is directed and which is molded or transformed into *outcomes* with the help of physical and symbolic, external and internal tools, which mediate the activity. The *community* is made of the actors who share the same *object* that shapes the individual and shared society. Engeström's *division of labor* refers to horizontal actions and interaction among the family members of the community actors and to the vertical division of power and status. The *division of labor* within a *community* involves *rules* and norms, each of which affords and constrain the goings on within a functional activity system. [Color figure can be viewed at wileyonlinelibrary.com]

The primary reason we selected CHAT as a framework was to leverage the idea of co-configuration to describe how the researchers and students negotiated the design and enactment of ecology research. Co-configuration has several characteristics, including

- services that are informed and performed by various participants;
- established processes by which participants can exchange information and ideas;
- ongoing and codeveloped customization of products and practices over time;
- mutual learning from interactions among the community's participants (Engeström, 2004).

The characteristics of co-configuration show that as activity systems interact around new problems, each participant plays a crucial role in identifying problems, developing solutions, and negotiating practices to continue innovation. Importantly, community learning occurs as participants confront tensions and reassess the effectiveness of their efforts to solve problems. In this study, CHAT helped the researchers see that while Lepidoptera and ecology formed the foundation of the unit, neither we (the researchers) nor the teacher chose to prescribe the exact practices or methods students might design and use to study moths. Thus, CHAT helped the researchers make purposeful decisions about how and why to redistribute epistemic responsibilities to students.

3.2 | Epistemic agency in co-configuration

While CHAT provides a foundation for examining the ways in which activity systems interact around novel problems, the theory is underutilized with regard to *how* participants interact. Such research is crucial to understand the processes of co-configuration on a smaller scale than organizational learning, the historic home of CHAT analyses.

We argue that co-configuration requires constant negotiation of epistemic practices (Eriksson & Lindberg, 2016). In particular, we propose that co-configuration hinges on actors' being positioned with, perceiving they that they can act, and acting with epistemic agency—the power for individuals and groups to shape the knowledge production and practices in a setting (Damsa et al., 2010; Dotson, 2012; Miller et al., 2018; Stroupe, 2014). Epistemic agency is necessary for actors to negotiate knowledge practices and production, which are foundational for co-configuration. From the perspective of this study, if teachers and visiting scientists positioned students as technicians, the adults would retain the agency to act as the sole content and pedagogical authority. However, we wanted to understand how students begin to take up epistemic agency to engage in co-configuration.

3.3 | Sciences from below

While seemingly easy to consider—having students take up epistemic agency to shape epistemic practices and thus engage in co-configuration—the notion that students and adults should have similar forms of epistemic agency may seem puzzling for two reasons. First, adults have constructed expertise that students have not yet developed. Second, the questions that science and society want answered do not typically involve K–12 students. However, we argue that co-configuration in activity systems implies that all participants should have opportunities to engage in and shape the epistemic practices of a community. Therefore, from a CHAT perspective, teachers, visiting scientists, and students should engage in similar agentic actions around epistemic components of a learning community.

We therefore used Harding's (2008) notion of "sciences from below" to understand how students, who are typically marginalized from full agentic participation in science practices, can be elevated to the same plane of epistemic activity as adults. Emerging from standpoint theory, "sciences from below" proposes that people without power are purposefully positioned as unable to achieve the same forms of agency in science as other and more powerful people. Harding notes that people with power shape social structures to define who can know, what is known, how things become known, and why people believe what is claimed to be known. Historically, such power dynamics rarely shift because those in power choose not to change, and those without power simply cannot shape an activity system.

To position students with opportunities to act as epistemic agents in the co-configuration of Lepidoptera research, the adults (the research team and sixth-grade teacher), purposefully chose to disrupt the typical epistemic power structures in classrooms. In other words, we chose to pay attention to students' perspectives "from below," and to disrupt the assumption that adults and students should not occupy the similar agentic planes of epistemic participation in school science. To do so required us to transform the participatory and pedagogical practices students typically encounter in science classrooms.

4 | METHODS

4.1 | Codesign research

Given the CHAT framework and dual roles as coinstructors and researchers, we viewed this study as a codesign experiment. By codesign experiment, we mean that we simultaneously engineered particular forms of learning in collaboration with a sixth-grade teacher and students, while engaged in a systematic study of learning within the classroom (e.g., Penuel, Fishman, Cheng, & Sabelli, 2011). As Seveance, Penuel, Sumner, and Leary (2016) note, codesign hinges on all participants having a voice in the design and analysis of practices. In this study, we engaged in reflexive revisions to the instruction, to the Lepidoptera research projects codesigned by sixth-grade students, and to the data collection and analysis techniques (Horn & Campbell, 2015). Note that while the research team planned the initial unit structure, students shifted the trajectory of the unit and the epistemic priorities as the unit began and progressed (see the Findings section for an exploration of student participation in the codesign process).

By conducting a codesign experiment, we hoped to understand the results of a research team planning and enacting an unit that featured student-designed research without a predetermined outcome. As O'Neill (2016) argues, we attempted to avoid the "heroic designer myth" that we, as the designers and researchers, should always know the path and outcomes of a codeveloped unit. While we felt initially unmoored as researchers, working with students and a teacher as active participants in the design process rather than subjects following a prescribed plan, such participation led to outcomes and opportunities for students that we could not have predicted prior to the study.

4.2 | Context

The context for this study was a sixth-grade science classroom in a middle school (Grades 6–8) near Michigan State University. We cotaught an ecology unit to three sixth-grade classes with the teacher each day for 22 instructional days, interacting with 90 students (30 per class). Each class lasted 55 minutes.

4.2.1 | Unit Trajectory

The 3-week unit consisted of two phases of collaboration. First, the university research team and Jake (the teacher) spent 10 hours planning the initial unit, including the activities and learning goals. We also decided on initial research questions, data collection, and outcomes we hoped to witness. Finally, White taught the coauthors and teacher how to build and maintain the moth traps the students would eventually build and use (see Figure 2 for an overview of the moth trap). The second phase of collaboration occurred as the research team (Jake and the university personnel, defined below) taught the three class periods, co-configuring Lepidoptera research with students over 22 days. We describe these processes in greater detail in the Findings section.

4.2.2 | Participants

University personnel

The university personnel consisted of three faculty members, and three undergraduate students who were all members of White's research laboratory. Stroupe is an assistant professor of science education at Michigan State University. White is an assistant professor of biology at Michigan State University, who specializes in Lepidoptera ecology. Caballero is an assistant professor of physics education and computational learning Michigan State University. For this study, Caballero designed and maintained the website students used to identify and update moth information (isthatmymoth.org; however, the website is no longer in use). Two of the undergraduate students previously worked during summers as research assistants in the Lepidoptera ecology with White; the third student just joined the lab and was beginning her training.

Sixth-grade teacher

Jake has been a teacher in the same district for 25 years. Jake was selected for two reasons. First, Jake's history in the district is filled with collaborative experiences with researchers. He seeks out opportunities to work with partners from the Michigan State University, and seemed eager to participate in the project. Second, Stroupe worked with Jake on a previous research project, and observed his teaching over 3 years. Jake's instructional history demonstrated that he attempts to provide students with agency to shape science and pedagogical practices. Therefore, Jake's vision of teaching and instructional history aligned with the conceptual goals described previously.

Students

Ninety students (three classes of 30 students each) participated in the study for 22 instructional days. Students came from diverse racial, social, economic, and cultural backgrounds. At the beginning of the unit, students reported that while they engaged in previous science activities, this unit was the first opportunity they had to conduct an extended investigation with a university-based research team. We purposefully selected these three classes because of their unfamiliarity with science investigations and because the classes occurred consecutively, thus facilitating the daily teaching and research work.

4.3 | Data sources and collection

We collected and analyzed multiple forms of data from three different types of episodes: planning sessions and communication, classroom observations, and artifact collection.

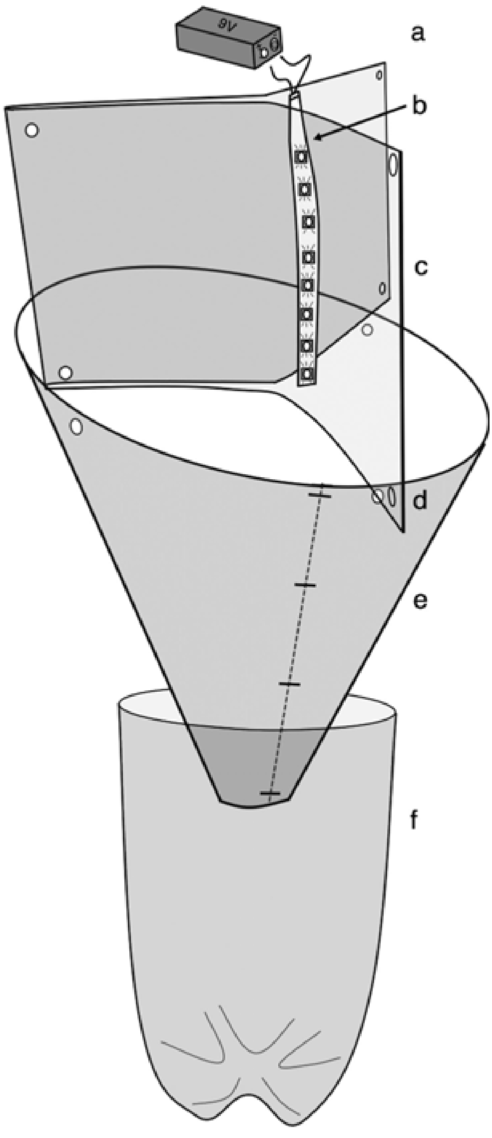

FIGURE 2 The moth trap uses a 9 volt battery (**a**) to power a two-sided low-wavelength LED light strip (**b**). This light strip sits in the center of a piece of Plexiglas that has been folded into three flaps (or vanes, **c**). The vane apparatus is tied to a funnel through a series of holes (**d**). The funnel (**e**), made of a cheap plastic placemat, is taped to the bottom of a 2L pop bottle (**f**). At night, moths fly towards the low-wavelength light, collide with the vanes, are then often collected by the funnel and deposited into the bottle where a small piece of household pesticide (2,2-*dichlorovinyl* dimethyl phosphate) is used to kill any collected specimens. The trap can be suspended from a branch or pole using the holes at the top of the vane apparatus. Students were given the bucket, the vane apparatus, the material for the funnel, and the light strips (attached to the battery), and were tasked with assembling their own trap

4.3.1 | Planning sessions and communication

This category of data involved requested or informal planning (such as email communication). When engaged in planning conversations with Jake, we paid attention to his pedagogical reasoning, how he framed problems of practice, and his vision of teaching. As researchers, we recognized our influence on the Jake's thoughts and actions, just as we valued and used his insights in our collective planning. Each conversation was video or audio recorded.

While most conversations occurred in person prior to the unit's first day, we collected multiple emails about planning throughout the unit. Jake's emails often requested help in preparing or reviewing upcoming lessons, assessments, or activities. In addition, Jake wrote to us with ideas, critiques, and questions about potential features of the unit. We saved each email and coded them as part of data analysis (see the next section).

4.3.2 | Classroom observations

The second set of data we used for this study was classroom observations, which we video recorded. Using two video cameras at different angles in the classroom, we video recorded each lesson during the entire unit for a total of 66 observations (three classes per day for 22 days). The purpose of the daily video recording was document the events and classroom talk that developed over time.

Jake and the university personnel informally debriefed after each lesson. During these 10–15 minute conversations, we scripted notes as everyone described the successes and challenges of the lesson. In addition, we discussed particular actions (e.g., why Power Point lecture was used) and actions that appeared unplanned or spontaneous (e.g., why a teaching episode was skipped even though it appeared on the daily agenda).

4.3.3 | Artifact collection

During each classroom observation, we recorded any learning objectives, warm-ups, and closing statements written on the board. In addition, we collected teacher and student-created documents related to planning, instruction, and reasoning for each lesson and all work associated with the classroom context, including lesson plans, assessments, instructions for activities or tasks, Jake's analysis of student work, and tools (created, modified, or adapted by participants to solve problems). We gathered the artifacts at the end of each lesson, or if they were in temporary spaces (such as a dry erase board), we took photographs and saved them to an external hard drive.

4.4 | Data analysis

In this section, we describe the two coding schemes and other analytical techniques used to identify patterns and make claims about the data.

4.4.1 | Coding Category 1: Elevating students to epistemic agency

Given that students are often positioned as technicians, we wanted to know what happened as students were elevated from marginalized roles as technicians to epistemic agency. Therefore, we coded the data for four possible opportunities in which students could be explicitly positioned with epistemic agency, perceive themselves as epistemically agentic, and to act with that agency (Miller et al., 2018):

- *Opportunities to solicit and build on student knowledge as a resource for learning*: Science education holds a consensus view that students' understanding should be used as a productive resource in instruction (e.g., Warren et al., 2001). We coded for ways in which students' community and culturally based intellectual resources were used for knowledge building.
- *Opportunities to build knowledge through participation in practices*: Another broadly endorsed idea is that students should construct knowledge through their participation in science practices (National Research Council, 2012). We coded for ways in which students could construct, question, and communicate knowledge.
- *Opportunities to build a knowledge product that is useful to students:* Berland et al. (2016) argue that when students monitor their progress toward learning goals, they develop deeper understanding of the ideas and practices. We coded for ways in which students selected, developed, and monitored their work toward their learning goals.
- *Opportunities to change structures that constrain and support action*: Students can act as change agents in the local and global structures that constrain and support tangible action (Fusco, 2001). We coded for ways in which students produced an effect on the world of their classroom community (Kaptelinin & Nardi, 2006).

4.4.2 | Coding Category 2: Co-configuration of Lepidoptera research

The second category of codes aimed to identify the processes of how the research team and students co-configured Lepidoptera research. We coded the participants' talk moves, pedagogical practices, and resources used to participate in the classroom learning community. We wanted to document how the participants were able to navigate tensions about the co-configuration process, rather than merely name the problems that arose.

Since CHAT theorists examine participants' interactions between activity systems, they look for learning to appear through contradictions within and between systems (Engström, 2004). As Engeström (2001) notes, "contradictions are not the same as problems or conflicts. Contradictions are historically accumulating structural tensions within and between activity systems" (p. 137). When individuals begin to question current practices, the contradictions that arise between participants can lead to new practices and expansive learning as they redefine the rules, division of labor, and object (Daniels & Warmington, 2007). In this study, we coded for contradictions around the following guiding questions, which are frequently asked in analyses of power and epistemic roles (e.g., Knorr-Cetina, 1999):

- Who was allowed to name problems and why;
- Who had a voice in the methodological decisions and why;
- Who decided the grounds for evidence in experiments and why;
- Who was allowed to decide data analysis and representation methods and why;
- Who could disseminate results to the public (classroom community and beyond) and why?

Such guiding questions illuminated how actors, including students, began to shift epistemic roles and thereby shape the practices, and engage in co-configuration, of the Lepidoptera research.

4.4.3 | Member checks

Throughout the unit, we had many opportunities to conduct member checks with all participants—the university team, teacher, and students. We asked participants to respond to our interpretation of the data, with the freedom to clarify, expand, or refute our interpretations during class time, over email, and during conversations (Merriam, 2009).

4.4.4 | Triangulating data

The final stage of analysis involved examining the codes for each of the data sources to look for patterns in our data. After coding each data source, we triangulated our data by looking across data sources to find supporting or disconfirming evidence across data sources to enhance the credibility of the codes and subsequent claims (Merriam, 2009).

5 | FINDINGS

We build this section around two central claims. First, contradictions emerged between participants Stroupe, Jake, and White during the initial planning with regard to students' epistemic roles and the purpose of the Lepidoptera research. The contradictions resulted in planning compromises about the purpose and structure of the unit. Second, during the ecology unit, students questioned the initial plans of the research team and pressed for different and unexpected forms of epistemic participation during the design and implementation of Lepidoptera research.

To organize this section, we first describe the tensions and proposed solutions developed by the research team during initial planning (unless otherwise noted, all quotations come from the video and audio recordings from planning and classroom interactions). Second, we provide a brief summary of the ecology unit week by week. We then use the four opportunities for epistemic agency described in the Methods section to highlight important moments in which students and the research team co-configured the Lepidoptera research.

5.1 | Claim 1: Contradictions when planning for epistemic agency

As noted, contradictions emerged between participants Stroupe, Jake, and White with regard to students' epistemic roles and the purpose of the Lepidoptera research. In this section, we describe how the research team negotiated the purpose and structure of the unit during planning.

5.1.1 | Planning for epistemic agency: Students' epistemic roles

When planning the unit, we considered how students could take up epistemic agency, thus shifting typical roles in classrooms. Given our varied perspectives, two primary contradictions emerged during the planning conversations: uncertainty and the role of adults.

Planning tension and proposed solution 1: Uncertainty

Purposefully planning opportunities for students to perceive and to use epistemic agency required the research team to imagine the uncertainty of what students might say and do as their roles shifted. While we could anticipate some of what might happen, uncertainty became a primary concern of the team when considering the co-configuration of research projects in small groups. Our concern stemmed from a core feature of epistemic agency that students should shape the knowledge production without someone else possessing a prescribed answer and eager to "fix" their "misconceptio ns." Therefore, we knew that students should have a voice in the questions they pursued, the evidence they collected, and the analysis they performed. Yet, as White noted, "what problems will they even decide to work on?" White was concerned that, if students were not guided by the research team, they may choose questions that are "overly naïve" (e.g., do moths like parking lots?), questions that have already been answered in the scientific literature (e.g., what color of light best attracts moths?), or questions that may result in correlated variables that were unlikely to represent a causative relationship (e.g., do neighborhoods with more residential swimming pools have fewer moths?). In other words, White wanted students to engage in "meaningful science" that could contribute to scholarly Lepidoptera research.

Jake noted that our lack of information was "scary," but suggested that even if student questions were somewhat naïve, or included variables unlikely to be causatively related to moths, that student would still "see, in real time, what it's like to design work when a grown up does not know the answer. That's powerful." Stroupe agreed, noting that "I'm trying to think about how kids can participate in science differently. I want there to be multiple paths of interest, beyond something like just temperature." White agreed, but noted that his dearth of K–12 experience impacted his ability to foresee the kinds of questions students might ask.

Given that we could not yet predict the paths that might spark student interest, nor could we know what students might say and do, we proposed a two-pronged solution. First, the research team, including the undergraduate students, agreed to divide the students into small groups and to facilitate their brainstorming conversations. By each working with one group, we planned to pool together student ideas at the end of each class during a daily debrief. In addition, working with one group seemed less daunting than having one person, such as Jake, take responsibility for facilitating multiple small groups in each class.

The second negotiated solution was to elevate students' ideas to the public plane of talk and interaction. As Jake noted, "We, as adults, can keep an eye out for ideas that seem important but that kids may not notice, and can call attention to those." In other words, the research team could identify and signal to students when their ideas might lead to promising research projects. We purposefully planned to avoid "right answer talk," such as telling students when their ideas were "right" or "wrong." Instead, we planned to signal the importance of students' ideas if they, or other students, did not notice the value of the idea. This was particularly important in trying to help students avoid questions that were naïve, redundant (in the scientific landscape), or unlikely to produce meaningful ecological relationships.

Planning tension and proposed solution 2: The role of the adults

The second contradiction when planning for epistemic agency emerged as we realized that our role in the classroom inherently involved power differences. We, as adults, were given responsibilities and power that students do not typically possess. Therefore, we considered how to redistribute some power to students, and what our role should become over the course of the unit.

Jake, as a veteran teacher, saw little difficulty in prompting students to take on new roles. He noted that "I'm not too worried about the curriculum. This will have lasting effects beyond memorizing facts. I'd rather students know that they can do science." Jake's sentiment was shared by Stroupe, and he proposed that the research team and students "co-learn about ecology." Stroupe noted that while each of the research team members has expertise in ecology and pedagogy, the team should be ready to learn with students as they ask questions that emerge from their local communities and experiences. White agreed, and said "I would love for this to start looking like my ecology lab, where my students and I talk about the research we want to do together." Thus, all senior members of the research team agreed that students should take up at least some measure of epistemic agency.

While the team agreed about the message to send to students about epistemic agency, questions remained about *how* to provide students with opportunities to perceive and use epistemic agency. Jake noted that the research team members had an important role because "students are not likely to just do this on their own. They'll want our permission since that what they think school is about. But, we want them to help us find solutions, not just memorize answers." White agreed, adding "We do have a job. We need to help the students design research problems," noting that it often takes time and practice to learn to ask high-quality scientific questions. Stroupe proposed that while the adults did have an important job initially, over the unit, the adults should purposefully provide opportunities for students to take up epistemic agency rather than act as technicians.

To provide such opportunities while acknowledging the important role adults play in the classroom, we negotiated two solutions. First, we wanted to establish initial routines and norms for talk at the beginning of the unit so students could participate in Lepidoptera research in real time. However, we planned for students to actively shift the norms and practices as the unit progressed. Second, and given the length of the unit (3 weeks), we planned to "accelerate" some thinking so that students could focus on the research data collection and data analysis. We decided that during our daily debriefs, we would take note of important student ideas or questions to highlight in the following lesson, so that the entire class could benefit from everyone's thinking.

5.1.2 | Planning for epistemic agency: The purpose of the Lepidoptera research

When planning the unit, we considered how students could co-configure the Lepidoptera research. Given our different perspectives, two primary contradictions emerged during the research team conversations: instructional goals and classroom logistics.

Planning tension and proposed solution 1: Instructional goals

The first contradiction about the purpose of the Lepidoptera research that emerged during research team conversations involved the instructional goals for students. White wanted the students to both become excited about science and to generate data that could be used to answer ecologically meaningful questions. For example, White envisioned geographic information systems (GIS) applications of the data in mapping species ranges to urban landscape features or identifying hotspots of invasive species occurrence.

Jake, the teacher, agreed with White's desire to instill passion for science in the students, but he questioned whether the ecological relevance of student questions and the subsequent quality of data should be a primary focus. Jake considered the success of individual students, particularly students who feel "left out of science" in school. Jake's goal was to find out how each student wanted to participate in the unit and to ensure that individuals had some means to achieve a perceived scientific success, regardless of whether their efforts added to the extant body of scientific literature on moth urban ecology. For example, Jake suggested students could document the relationships between nighttime temperature and moth diversity, size, wingspan, or other characteristics. However, White noted that the relationship between ambient nighttime temperature and moth abundance or diversity had already been fairly well established; more moths (and greater variety of moths) are generally caught on warmer nights.

This conversation highlighted an undercurrent of contradiction that existed throughout the project. White, a moth ecologist, prioritized having students examine ecologically meaningful relationships—being willing to sacrifice a measure of their epistemic agency in the process—whereas Stroupe and Jake prioritized students' use of epistemic agency regardless of the value of their questions within the landscape of the greater scientific community. In this sense, White recognized that more control over student questioning would likely lead to reportable scientific outcomes. Alternatively, Stroupe and Jake's approach resulted in less concern over the quality student questioning, but pushed for giving students “a voice in deciding the research projects about moths they will undertake.” For example, Stroupe wanted students to consider what they find “interesting about moths” and to design research to advance their understanding of their initial interest. While agreeing “with your sentiment,” White noted that “we have to be true to science—kids can't just compare variables that may not be causally related” during the unit. Stroupe and Jake agreed, but argued that students needed to drive the analysis of why variables may not be causally related. In addition, Jake proposed that White could help students understand what makes for a good scientific question in the arena of urban moth ecology. Stroupe agreed and added that, in addition to access to White's thinking, the research team should provide students with opportunities to question White's scientific thinking and to propose their own questions and research projects.

Given the contradictions about instructional goals, project outcomes, and planning opportunities for students to act as epistemic agents, we proposed three initial solutions. First, we planned an initial trajectory of teaching and science. We proposed that White introduce students to moths and to briefly describe their importance in ecosystems. Next, White's undergraduate students could help Jake's students build moth traps for the purpose of testing the traps and to collect a few initial moth samples. Finally, the research team could help students plan research projects, paired with appropriate sampling methodologies to investigate their variable(s) of interest.

Second, the research team agreed upon a set of variables—total moth biomass, moth abundance, and morphospecies diversity—that students could measure across research projects. This agreement was tentative since Stroupe argued that students should have a voice in selecting the variables, but White and Jake agreed that these variables could, at minimum, provide a foundation for the projects.

Third, the research team discussed how to prepare for unanticipated weather phenomena and the subsequent impact on moth trapping. White noted that rain or cold temperatures persisted during the night, moths would not be very active, resulting in very low trap yields. Therefore, if no students catch moths during the night, the subsequent class will lack any specimens to identify. Jake suggested that the class needed a “moth alert system” to inform them of the plan for the evening. In the end, we decided that trapping decisions would be made every day, in class, based on the hourly weather forecast for the coming night.

Planning tension and solution 2: Classroom logistics

The second tension about the purpose of the Lepidoptera research that emerged during initial research team conversations involved the logistics of enacting the unit in the reality of classroom life—three different periods that lasted only 55 minutes each day. White expressed concerns about being able to conduct adequate “lab work” in such a short span of time, thinking of the specimen sorting and pinning, data logging of the previous night's catch, along with other classroom activities (like taking attendance, making announcements, and weather forecasting) that would need to be done each period. White noted that this challenge would be exacerbated if nighttime temperatures were warm (i.e., greater than 60°F/15°C), resulting in single-trap yields of dozens of moths, possibly resulting in hundreds of moths in each class. In addition, White explained that the student moth traps might need regular maintenance and repair. Therefore, White advocated for a policy of students bringing moth traps back into class if they needed to be repaired.

Jake acknowledged White's logistical concerns, but joked that “this will be a very different kind of ecology lab than you are accustomed to working in.” While this did not address any of White's concerns about classroom logistics, the team proceeded without a solution to this potential problem, hoping for moderate-to-low trap yields that would not overwhelm the classroom time and faculty. Jake, with the hope of manageable yields, proposed that the primary responsibility of the research team was to set the “pace of each class” and then to make sure students worked toward the goals for each day.

Stroupe agreed with Jake about establishing a daily routine for each class, noting that a routine could shift "depending on the work we're engaged in each week." However, Stroupe noted that the research team should be ready to "adapt a routine based on students' emerging needs." Stroupe noted that planning routines and sticking to them with fidelity would undercut students' opportunities to act as epistemic agents because they would not have a voice in shaping the daily science work. Stroupe's primary concern was that the research team should consider whether to have students work in small groups on research projects, or work on one research problem per class period. Jake suggested that students should "see research from multiples angles," and he proposed that each class engage in a large project in addition to students' selections of a smaller projects that they could shape in groups. This was a sentiment shared by White who hoped that, while students could collect data to answer their own small-scale questions, the data from an entire class (or across all three classes) could be compiled and be used as a larger data set to explore relationships between moth assemblages and the urban environment.

Given the tensions about classroom logistics and planning opportunities for students perceive and act with epistemic agency, we proposed two initial solutions. First, the research team agreed to create two opportunities for students to participate in different forms of Lepidoptera research by designing research in small groups (beginning in the second week of the unit) and by recording data and looking for patterns on a problem identified by Jake at the beginning of the unit—the relationship between weather and moth biomass. Each class period, the students and Jake would record information from a weather website about the previous night's conditions, such as temperature, humidity, and precipitation. They could then compare the weather data to the biomass, abundance, and diversity data collected during each class. While the relationship between nighttime weather conditions and moths was not a question that any of the groups chose to engage in, it was a good way to model the process of exploring a relationship between a dependent and independent variable (e.g., moth abundance vs. nighttime temperature).

The second initial solution for classroom logistics involved moth traps. The research team agreed to help students build the moth traps during one class period at the beginning of the unit. The traps were complex enough that students could likely not build them alone, but White's undergraduate students could help each student build a trap in one class period. In addition to the initial assistance, the research team agreed that students could bring traps in need of maintenance back to class, where an undergraduate student could set up a repair station during each lesson. The students could deposit the trap with the undergraduate student at the beginning of class, and by the end of class the undergraduate student could repair the trap to send home with the student.

5.2 | The moth unit

Despite planning for opportunities for students to perceive and use epistemic agency, real-time classroom instruction prompted students to question the initial plans of the research team and press for different and unexpected forms of epistemic participation during the unit. In this section, we outline the trajectory of the 3-week unit, noting the negotiated decisions and events that unfolded over time.

During Week 1, five primary events occurred. First, the research team brought in samples of moths (pinned in boxes) for students to observe. Students recorded their observations, some of which became foundational for designing research projects (such as moth color and camouflage possibilities on trees). Second, students learned how to pin moths using specimens caught by the undergraduate students. Third, students built moth traps with the help of the research team. Fourth, students attempted an initial night of trapping, and brought back any specimens to class the following day. Fifth, Jake and the students engaged in the first whole-class discussion about the moths while recording information about the captured moths in notebooks.

During Week 2, five primary events occurred. First, students continued to compile data about moths from initial trapping opportunities, and they, along with Jake, noticed fewer moths appearing in traps. Second, each period engaged in a whole-class conversations about observations they noticed when engaged in initial trapping efforts. Third, based on the observations, students selected a topic group for their research projects. Fourth, students in each class codeveloped research questions with the research team. Listed here are the research topics from each class period:

- Class 1: (A) Does tree type matter for moth biodiversity (i.e., deciduous vs. coniferous)? (B) Will we catch more moths on properties with water features (e.g., ponds and streams) or on properties without water features? (C) Are moths attracted to traps placed near artificial lights (e.g., house lights and streetlights) or traps placed far away from artificial lights?
- Class 2: (A) Do moths have a color preference for flowers? (B) Does proximity of water impact moth biodiversity (i.e., similar to 1B above; here the students wrote and distributed a survey to classmates and planned to triangulate this data with moth trap data)? (C) Does the brightness of trap light impact moth abundance?
- Class 3: (A) What is the effect of tall grass or short grass have on moth biodiversity? (B) Do we catch more moths by tall or short trees? (C) Are moths attracted to traps with light or traps without light?

Fifth, each student-led research team planned the logistics of research, such as trap placement, a system for reminding each other to collect the moths, and the nights when the traps should be set out to capture moths.

During Week 3, four primary events occurred. First, students continued to compile data about moths from initial trapping opportunities, and they, along with Jake, noticed more moths appearing in traps given warmer temperatures. Second, students set out traps and collected moths, which they brought back to class each day. Third, students and the research team established a daily routine for each class—identify moths, pin moths, record data on class sheets, and discuss data and procedures with the research team. Fourth, students began to answer their research questions with their team.

5.3 | Claim 2: Classroom instruction

Given a brief overview of the major events that occurred during the unit, we now provide examples of how students and the research team engaged in almost daily co-configuration of the Lepidoptera research using the four opportunities for epistemic agency described in the Methods section.

5.3.1 | Opportunities to solicit and build on student knowledge as a resource for learning

As noted in the summaries of the planning contradictions and moth unit, the research team anticipated that students might be concerned with providing "correct answers" rather than stating ideas to revise over time. Therefore, the research team purposefully and publicly attempted to position students and their ideas as foundational for the Lepidoptera research. Here, we provide examples of students' participation in terms of their epistemic roles and co-configuration of Lepidoptera research.

Students' epistemic roles

A primary goal of the research team was to elevate students from the margins of participation (as technicians) to a role of epistemic agents. For example, White and the undergraduate assistants taught the students, Stroupe, and Jake how to pin moths onto a spreading board. The entomologists caught moths for each class, and they both demonstrated and assisted people pinning moths for the first time. During the pinning process, the research team embedded themselves in small groups of students to both help and to remind students that pinning would be an important part of the upcoming unit work. For example, Jake told students to "pay attention and ask lots of questions about how to pin. You'll be doing this in the coming lessons." White added to each class, "When you collect moths from your research designs, you will pin them to help identify them. We're showing you how to do it so that you can do entomology research." White repeated this statement to each group in every class.

In another example, students built moth traps to catch moths at home. White and the undergraduate assistants developed a technique to build cheap moth traps (materials cost $30 per trap; see White, Glover, Stewart, & Rice, 2016), and they provided materials for pairs of students in each class to build traps. In each class period, White and the undergraduate assistants demonstrated how to build traps and helped students build the traps. During the trap building, the research team explicitly told students that this work would provide a foundation for the research projects.

In addition, several students pinpointed features of the trap that might be modified. For example, one student noted that "maybe moths like a different colored light than the purple LED light we have." Jake replied "That's an interesting idea to propose when you are designing research projects." Although no groups decided to examine the impact of light color on moth catch yield, this example highlights the challenge of positioning students with epistemic agency—when should students be given the answer to a scientific question (provided it is known), and when should they be encouraged to proceed down a road with a predictable outcome? Here, White, who had expert knowledge of the moth urban ecology scientific literature could have answered students with the previous findings related to this question (e.g., Van Langevelde, Ettema, Donners, Wallis DeVries, & Groenengijk, 2011). However, Jake was focused more on the process than on the novelty of the science and thus signaled to the student that his idea could be a worthwhile venture.

The purpose of Lepidoptera research

Our primary focus as a research team was to position students' ideas as foundational for shaping the Lepidoptera research projects. To begin this process, Jake introduced the research team on the first day of class and noted that "the scientists need your [the students] help to answer questions about moths and ecology they don't know the answers to yet." This introduction led to immediate questions and comments from some students, such as "I thought scientists knew everything," "How can we help scientists when we're in 6th grade," and "Why do scientists need our help? Don't they have workers?" In each case, White noted that science (in particular, moth ecological research) does not often involve an investigation of processes occurring at small scales, within local communities. The data that they could therefore collect, would present an interesting opportunity to examine ecological relationships at a unique scale. An undergraduate assistant, Paul, added that, with their help, we might be able to discover new things. After the introductory remarks in each class, White, as planned, initiated brief whole-class conversations with students about his work as an entomologist and gave an overview of the unit. He told students that "Right now, we're going to get you up to speed on moths. The next two weeks, you'll start to take over the class and do more of the science work." Jake added on to White's overview, noting that "it's rare to get a scientist in the classroom once, much less to have a team of researchers here for three weeks."

Note two features of the introductory conversation about epistemic agency and students' ideas. First, many students wondered how they might engage in science if the scientists did not have answers. In other words, students indicated that they expected the scientists to tell them what to do rather than have a voice in conducting science. Second, given the students' skepticism, the research team—from the beginning of the unit—worked to position students with power to shape the science work of the classroom.

In Weeks 2 and 3, the research team continued to position students' ideas as foundational for Lepidoptera research. For example, when students learned to pin moths, one group of students noticed that certain moths had dull colored wings, whereas other moths had bright colored wings. An undergraduate assistant, Hannah, pressed their thinking to consider research implications:

Student 1: Whoa, this moth has blue lines on the wings.
Student 2: Wait, this one is really dull.
Student 3: So is this one.
Hannah: Why do you think that might be?
Student 3: Because this moth [points to "dull" moth] lives by dull colors, and this moth [points to blue-lined moth] lives by blue colors.
Student 1: So, they try and hide?
Student 2: Maybe.
Hannah: Maybe next week you all can think about how to answer the question. We're going to have you design some research about moths, and if wing color is interesting, you can figure out how to study it.

Note that Hannah did not tell students a canonical answer to the question. Rather, she positioned students as capable of future research design work to investigate their initial observations.

5.3.2 | Opportunities to build knowledge through participation in practices

At the beginning of the unit, the research team worked to purposefully position students as capable of participating in ecology practices. As noted, such efforts included teaching students to identify and pin moths, helping students build traps, and analyzing data about weather patterns and moth abundance. After Week 1, students began to shape the practices rather than the research team serving as the sole decision makers about such work.

Students' epistemic roles

A main purpose of the unit was to provide students with opportunities to redefine their epistemic roles, and this goal was actively stated by the research team to students almost daily during the first two weeks of the unit. For example, White expressed the uniqueness of small-scale, local data collection to the class "I want you to discover something about moths and how they interact with their environment. What kind of things, variables, do you have at your house that we could test. We need to make decisions about what we want to find out." Such statements, made by the professional scientist, were important for students to hear since White appealed to students' lives as important for determining the research projects.

An unexpected outcome of students' shifting epistemic roles emerged on one of the last lessons during Week 3. One student, John, and his group tested moth abundance when the traps were close to light or placed far away from a light source. John told his group that he had a woodlot behind his house, and that his group should place the traps in the trees to avoid light. They agreed, and John's woodlot became a primary location for "light-free" traps. At the end of Week 3, John brought in the moths collected in the trap and found Stroupe:

John: I found this cool-looking moth and I can't figure out what it is. I looked on our website but I can't find it.

Stroupe: I don't know what it is either. Since White isn't here today, let's find Paul [one of the undergraduate assistants].

Paul [walking over]: What did you find, John?

John; I don't know.

Paul: Hmmmm…I'm not sure what this is either.

Stroupe: Wait, so you don't know?

John: I thought you guys knew all of the moths.

Paul: I haven't seen this one yet in my lab work with White. John, let's look at the moth identification book together.

Note that Paul made two intentional moves to position John with epistemic agency. First, Paul admitted that he did not know the moth species, rather than invent a moth or dismiss John's specimen. Second, Paul invited John to look at the identification book with him, rather than position John as someone not permitted to coidentify the moth.

Word quickly spread about the unidentified moth, and students eagerly awaited the identification. Finally, Paul asked John if wanted to announce the result, but John asked Paul to make the announcement. Paul told the class that John caught an eight-spotted forester moth (*Alypia octomaculata*), and that to his knowledge, the entomology lab did not have a sample of the species. Students applauded, and some patted John on the back. When White returned the following lesson, he confirmed the identification of the moth, asked John if he could keep the moth as a "voucher specimen" in his lab, and asked if he could include John's name as the person who captured the moth. A student said "you're famous now, John!" While unexpected, John's discovery occurred because his group made decisions that the research team facilitated but did not mandate. Instead, John's moth was one outcome of student-driven research projects.

The purpose of Lepidoptera research

As noted in the unit summary, students' emerging epistemic agency became apparent during the design and implementation of the Lepidoptera research projects. During small group conversations about the research design, students had opportunities to voice suggestions, critique ideas, and negotiate solutions with their peers and the research team representative. For example, in Class 3, a large group of students (12) wanted to study the relationship between plants and moth abundance. Stroupe led the initial discussion, and during the conversation the group realized that half of the students wanted to pursue a different research project than the other students. As illustrated in the following conversation, students worked to both advocate for their preferred research project, while still encouraging their peers to pursue the science they found important:

Student 1: I just can't do tall grass versus short grass. That seems boring.
Student 2: My idea isn't boring.
Student 1: I'm not saying to you that you're boring. I just think that we'll get more moths if we trap by trees, not grass. So that's the boring part, just not getting any moths.
Student 3: How will we know if we won't get moths in grass unless we try?
Student 4: Can we do trees versus grass?
Student 5: I thought we had to pick one thing.
Stroupe: You don't have to pick only one variable to test. But think about two things. First, as White said, you can do a lot even with easy designs. Second, anything you propose has to get tested. How might you design a project to test grass and trees?
Student 6: Trees and grass sounds too crazy.
Student 7: Too much work.
Student 1: Well, I want to do trees.
Student 2: Can we do two groups of plants? Can we do one group of trees and one group of grass?
Student 1: I can do that.
Student 8: That sounds good to me because we are supposed to do something we want to do.
Stroupe: I agree. It sounds like this conversation was helpful to show that even one big category, like plants, can have different paths to study based on what you want to learn about.

Note that Stroupe did not resolve the dispute among students about the object of activity. Instead, Stroupe served as an arbitrator and legitimized the students' decision to split the group apart. This case highlights the tension between Stroupe and Jake's desire for students to use epistemic agency to design research they wanted to conduct, and White's push for science that advanced Lepidoptera research. It is well known, for example, that urban woodlots host a very different assemblage than grassy areas (see Rice & White, 2015), but the impact of mowing and grass height on Lepidoptera assemblages has not been well explored. Here, where White might have steered the conversation in a different direction, Stroupe encouraged students to make their own discoveries in this arena, given that they had no background in the relationships between moths and the urban environment.

5.3.3 | Opportunities to build a knowledge product that is useful to students

As noted in the summaries of the planning contradictions and moth unit, the curriculum goals for the unit focused on foundational concepts in ecology, such as food webs and the survival of organisms and populations. While those curricular goals remained important, the research team and students negotiated other knowledge goals as students designed research projects.

Students' epistemic roles

The research team continually negotiated students' epistemic responsibilities in deciding the instructional goals. During Week 1, the research team selected and led activities such as pinning moths. While such roles could have remained, the students' daily moth catch and emerging needs (such as trap repair) often necessitated immediate shifts in the instructional goals. By Week 3, the first 5 minutes of class—the time in which Jake and the students recorded weather data—became the opportunity for the research team to hear from students and to make instructional decisions. For example, if the weather was cold on the previous night and students caught few moths, the research team and students agreed to repair traps and label any moths not yet identified. If students caught numerous moths, the day's goals focused on pinning the moths and recording the capture site and weather on class data sheets. Thus, the day's knowledge goals depending entirely on students' needs at the beginning of class.

Another example of students' shaping the daily knowledge goals emerged as students gravitated toward particular practices. Some students preferred moth identification, and often volunteered to examine unidentified moths. Other students had an interest in trap repair and would help the undergraduate assistants with such work. Two students, Claire and Lily, developed an interest in pinning insects. While every student relished opportunities to pin moths, Claire and Lily became fascinated by pinning every insect caught in traps, including flies, ladybugs, dragonflies, and bees. Their interest caught the attention of an undergraduate assistant, Jenny, who worked with the students to become more proficient on pinning various insects. In addition, Jenny focused on questions the two students asked about insects during the pinning, such as body parts (Jenny named parts for the students, such as the thorax and abdomen), and behavior ("this yellow stuff on the bee's legs is pollen, which they were probably transporting back to the hive"). While the research team could have dismissed Claire and Lily's emergent interest, the students instead shifted their daily knowledge goals to learn about insects and to practice pinning.

The purpose of Lepidoptera research

As planned during Week 1, the research team introduced students to features of ecology work, such as capturing moths, identifying species, and recording weather conditions in a notebook. In addition, the researchers stated publicly that in the coming weeks, students would take on the responsibility for co-configuring research projects. These purposeful moves worked to establish the norm that students should have a voice in the design process and the upcoming instructional goals.

During Weeks 2 and 3, students began to shift toward epistemic agency around the knowledge goals of the class. This shift resulted in two different outcomes that hinged on students' increased responsibilities. The first outcome was that the knowledge goals began to reflect student voice. Student groups and their research team member negotiated the questions asked, the hypotheses generated, and the data collection proposed. For example, White worked with a group of students during Week 2 to finalize their plan to collect moth data. In this conversation, the students and White are negotiating the hypotheses they will test:

White: Ok, what do you think will happen if we try and catch moths with and without light on the porch?
Student 1: I'll think we'll get more moths with light.
White: Ok, now we're starting to hypothesize.
Student 2: Like, make a prediction?
White: Yes, but a prediction that we can actually test. Why do you think we'll catch more moths in the light?
Student 3: I think we'll catch more moths in light because they like it.
Student 2: Yeah, and without light, they can hide.
Student 1: Like hide from things that want to eat it?
Student 2: Yeah, the other things that want to make it dinner.
White: Let's use our ecology terms like predator.
Student 3: So, we think we'll catch less moths in the dark because they are camouflaged to hide from predators.

Note that White was pressing students to invoke required curriculum standards (the ecology terms) while still supporting their hypotheses. Also note that White distinguished a science practice (hypothesizing) and a colloquial variation of the science term (predict), while still positioning students as the primary designers.

5.3.4 | Opportunities to change structures that constrain and support action

As noted in the summaries of the planning contradictions and moth unit, the research team acknowledged that they were bounding student voice by selecting the unit and the focus organism. However, the research team also purposefully provided students with opportunities to decide how to use their lived experiences to shape the Lepidoptera research and to make clear how they wanted to use class time and resources to engage in the research.

FIGURE 3 Jake's Twitter feed, which shows the use of Samuel's term "pleasure trapping". [Color figure can be viewed at wileyonlinelibrary.com]

Students' epistemic roles

Students' desire to co-configure the Lepidoptera research resulted in the validation of their interests and an uptake of their ideas on the class level of activity. For example, on a nontrapping morning (meaning that students were not supposed to put out traps the previous night), a student, Samuel, brought in two moths. In the following exchange with Jake at the beginning of first period, Samuel christens a new term—"pleasure trapping" to describe his actions:

Jake: Oh, Samuel, I thought we were not trapping last night.
Jake: What do you like?
Jake: So, you enjoy trapping even when it's not part of the research project.
Jake: I like your idea of pleasure trapping. Can I tell the class about it?
Samuel: But I wanted to trap anyway. I like it.
Samuel: I like seeing if I'll catch anything the next morning.
Samuel: It's pleasure trapping.
Samuel: Sure.

Following this exchange, Jake announced pleasure trapping, saying to each class "I put on my Twitter account that we're not trapping tonight. But according to Samuel, there is such a thing as pleasure trapping. In other words, he's trapping because he wants to, not because we said so. He just wants to find a lot of moths" (see Figure 3). Jake's placement of pleasure trapping on Twitter, and his announcement to every class legitimized Samuel's idea, and positioned his as shaping the community's work as an epistemic agent—even on "nontrapping" evenings, students could still pleasure trap.

The purpose of Lepidoptera research

As noted in the planning and unit summary, the research team purposefully bounded the unit around moth ecology given the curriculum and expertise of the scientists. While moths became the focus, students questioned the research team's decisions about the goals of the unit. For example, in Week 1, Jake initiated the first whole-class journal entry to illustrate how to compile moth data and to demonstrate how to measure moth biomass. Jake guided students through each entry point in the notebook, noting the previous night's temperature, the number of moths, and other weather conditions. During the first journal entry, the research team attempted to obtain the biomass of the moths, as planned during the initial conversations. However, the scales were not sensitive enough to accurately gauge the biomass of the moths. Therefore, Jake announced, "we thought biomass might be a good measure, but now I'm not so sure. How do you feel about it?" A student replied, "If it doesn't work, why should we do it?" This student's comment prompted a shift the in future work of the class. Since biomass was not possible to measure in the class, we decided to discard that part of the data and to credit students for pointing out that such data would not help advance the class' research work.

In addition to students designing research projects, the whole-class notebook data provided students with an opportunity to see a correlation between weather and moth abundance that they quickly pointed out to Jake during Week 2. For example, a student in first period noticed that on the first night of trapping, the temperature was warmer and she caught two moths. On the second night, the temperature was colder and she did not catch any moths. During the whole-class discussion, the student stated, "I think if it's cold out at night, less moths will come out because it's like not as warm." Jake replied, "You anticipated what I saw too, which is that I caught something in warmer weather. I wonder if there is something to this." Note that Jake validated the student's idea and publicly positioned her observation as data the class should investigate further. While unplanned, the students' observations of weather and moth abundance became an important part of the class work during Weeks 2 and 3.

6 | DISCUSSION

Given the planning and unit trajectory, we revisit the research questions from the perspective of CHAT, epistemic agency, and sciences from below. We first describe how efforts to provide opportunities for students to perceive and act with epistemic agency required attention to two aspects of power dynamics—reframing agency as collective rather than individual, and reimagining participation. We then consider the role of the research team in facilitating the co-configure of the Lepidoptera research.

6.1 | Disrupting power dynamics

We first describe how efforts to provide opportunities for students to perceive and act with epistemic agency required attention to two aspects of power dynamics—reframing agency as collective rather than individual and reimagining participation.

6.1.1 | Collective rather than individual agency

As Severance, Penuel, Sumner, and Leary (2016) note, in order for systems to transform from historic modes of action to new forms of activity, agency must be collective and negotiated among participants rather than privileged among a select few. In this study, establishing a participatory norm of epistemic agency rather than technician agency required multiple participants within the classroom—the research team, teacher, and students—to negotiate students' epistemic roles and Lepidoptera research daily. However, none of the agentic decisions were the sole responsibility of one participant. In other words, the participants did not operate in isolation from each other; rather, the norms for epistemic agency were developed, tested, and revised in each class by the participants.

6.1.2 | Sciences from below: Reimagining participation

As noted, the research team purposefully provided opportunities for students to move from the margins of science to beginning to participate as epistemic agents. These purposeful opportunities were designed to both disrupt students' images of school science and to provide them with a new vision of who they could be as scientists. As Edwards and Kinti (2010) propose, people do not learn merely content or practices in an activity system. Embedded in knowledge and actions are messages about who a person should be—their identity, values, and vision of success. Therefore, the research team recognized the importance of shifting the participatory roles from the initial conversations during the first lesson. In addition, the research team needed to recognize moments in which students offered ideas and interests—such as Lily and Claire's pinning and Samuel's pleasure trapping—that could transform participatory norms if recognized and valued. Given the power differences between the adults (the research team) and the children (students), the research team needed to validate and promote students' emerging and unpredictable forms of epistemic participation.

6.2 | The role of the research team

We now consider the role of the research team in facilitating the co-configuration of the Lepidoptera research.

6.2.1 | Navigating uncertainty

As Manz and Suárez (2018) note, an immense challenge in codeveloping science with students is navigating the inherent uncertainty involved in scientific endeavors. While school presents an image of science as a linear and logical progression of experimentally proven facts, science in other settings must contend with a constant host of unpredictable factors (Pickering, 1995). In this study, the research team played a vital role in navigating the daily uncertainty that emerged, including trap repair, students' ideas, the weather, and moth abundance. While the team designed daily lesson plans, we also recognized the need for continued adaptation based on emerging factors. The research team structured the unit so that we were forced to reimagine our roles as we adapted to real-time tensions and surprises. Thus, the lack of control proved to be destabilizing in positive ways, both scientifically and pedagogically (Manz & Suárez, 2018).

6.2.2 | The meaning of physical presence

Since the university research team needed to interact with students to engage in co-configuring work, our physical presence was required in the classroom each day. While easy to overlook, the physical presence of the research team had a crucial impact on students' shifting epistemic participation and the unit trajectory. As Kallio (2010) argues, changes in activity systems cannot occur if the participants responsible for co-configuration are not able to meet and engage in conversations and activity. Since the university research team was present each day, the students could, for example, ask the team questions in the moment and receive instant responses. The university research team witnessed and participated in solving emergent problems of practice rather than viewing tensions from afar or after they happened. In addition, the research team's knowledge become public, and therefore a resource for everyone. Finally, the research team legitimized students' ideas, questions, and research projects. Had the team not been physically present, students' projects and participation may have differed.

6.3 | Revisiting co-configuration

We conclude this section by revisiting co-configuration and considering the epistemic agency possibilities of participants in a community with inherent power differences. One clear theme that CHAT helped illuminate was that co-configuration hinges on all participants making an active and continuous contributions to the epistemic practices in a community (Nummijoki & Engeström, 2010). We echo Engeström (2004), who argues that co-configuration inherently requires participants—including those on the margins of participation—to develop different forms of agency that previously do not exist. In this study, the research team purposefully provided opportunities for students to perceive and take up epistemic agency and altered their participation to redistribute some of their pedagogical and disciplinary authority to students. While each participant in the classroom had a vision and history of expectations for participation in school science, the co-configuration of Lepidoptera research forced constant negotiation of entrenched rules, norms, and participatory structures. Given the daily uncertainty, participants had to work together in real time to identity problems and develop solutions—the core of co-configuration.

7 | CONCLUSION

We conclude by considering the epistemic agency possibilities of participants in a community with inherent power differences and reflecting on CHAT as an analytical lens.

7.1 | Possibilities for epistemic agency

Given students' important role in co-configuring the Lepidoptera research, we note that students readily took up some form of epistemic agency during the unit. We are left with two questions.

First, what forms of epistemic agency should students develop in school science, particularly when inherent power differences exist between adults and children in a classroom? We recognize that from the outset, students' epistemic agency was bounded by the research team's selection of the unit topic (Lepidoptera), by the unit itself (ecology), and by the time constraints (22 days). Given those constraints, a primary goal was to see how students' agency might begin to shift from technician (solely engaged in work determined by others) to epistemic agency. We hoped to embody Hand's (2012) call for students to both assert their emerging identities and resources in a setting, and imagine (and actively work) to reshape the setting for their needs. In this study, we purposefully positioned students as capable of shaping the knowledge production and practices of the classroom. Because students asked questions that we could not answer, and because we could not be present in students' homes after class ended, students took on new epistemic roles in the classroom. In doing so, students and the research team began to co-configure the Lepidoptera research rather than the researchers deciding on the epistemic roles for students to follow.

Note that students' epistemic agency was in constant negotiation, and the research team approached the unit by not framing agency as binary. As Gresalfi (2009) argues, people exercise agency constantly, thus the notion that people "have" or "lack" agency is misleading. The story of this unit, then, is how students and researchers shifted agency from typical power differences to providing students with an opportunity to recognize and exercise epistemic agency and co-configure the Lepidoptera learning community.

Second, is it possible to both position students as epistemic agents and conduct science research that is meaningful to all participants? Clearly, tensions existed among the research team and Jake about the project goals. Stroupe and Jake wanted students to ask and answer scientific questions while taking up epistemic agency. White wanted students to be engaged ecologically meaningful scientific questions. While students' research did not add anything to the scientific body of knowledge on moth dynamics in urban environments, their work was meaningful to the students as a learning community. We wonder how we can empower students as epistemic agents and engage in research that is meaningful to both students and scientists.

7.2 | CHAT as an analytical lens

To conclude, we describe the affordances and constraints of using CHAT to frame and analyze this study. Throughout the process, we identified three ways in which CHAT was beneficial for this study. First, CHAT pushed the research team to account for each participant's perspective. To understand how co-configuration occurred, we had to understand how each participant shifted epistemic roles over time. Second, CHAT helped the research team name contradictions about students' epistemic roles and the co-configuration of Lepidoptera research, thus enabling us to have a foundation for developing solutions. Third, rather than claiming that the process of co-configuration resembled a light switch—off one moment and on the next moment—CHAT enabled the research team to understand that the process of co-configuration is neither easy nor quick and that describing the unit to readers should illuminate the messiness inherent in the work.

While CHAT was beneficial, we also found CHAT proved difficult as an analytical lens for two reasons. First, CHAT was limited as an interpretive lens. The research team needed to invoke other conceptual lenses (i.e., sciences from below and epistemic agency) to understand *how* co-configuration happened, not merely that the process occurred. Second, stories of individuals within an activity system can be hidden in the enormity of the co-configuration process. We did not describe all the instances of individual student learning because CHAT pushes researchers to look broadly in and across activity systems, rather than investigating how individuals experience the shifting activity and practices.

We continue to be inspired by Harding's (2008) call to shift sciences: "if we are to transform the sciences, we must also transform the larger social relations that end up giving content, form, and value to existing kinds of scientific inquiry" (p. 125). In this study, we found that school can be a context in which students—who are typically marginalized from epistemic agency in science—can co-configure Lepidoptera research with support from others. However, we propose that the onus is on us, adults and scientists, to provide opportunities for students to perceive and use epistemic agency, rather than hope that students might spontaneously take up new epistemic roles in schooling and standards systems that have historically positioned them solely as technicians. We need to uphold a bold vision of science teaching and learning, in which those typically without a voice in the classroom see that they can and should advance the knowledge production and practices as epistemic agents.

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ORCID

David Stroupe http://orcid.org/0000-0002-3471-0049

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